Economics & Business Management
ISSN Print: 3079-5214
ISSN Online: 3079-5222
https://doi.org/10.63313/EBM.9116

Digital Transformation and New-Quality Productivity: Evidence from Chinese Listed Firms

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How to cite this paper: Ge, T. T., & Pan, J. M. (2025). Digital Transformation and New-Quality Productivity: Evidence from Chinese Listed Firms. Economics & Business Management, 3(2), 129–139. ISSN Print: 3079-5214; ISSN Online: 3079-5222. https://doi.org/10.63313/EBM.9116
Published: 2025-10-28

Abstract

The deep integration of the digital and real economies has become a key engine for high-quality economic growth. This paper examines how firm-level digital transformation affects new-quality productivity—a qualitative upgrade in productivity driven by digital technologies, data assets, and organizational complementarities—using firm-level data for Chinese listed companies. I find three main results. First, digital transformation significantly raises firms' new-quality productivity. The effect is economically larger for non-state firms and for firms operating in more competitive (less monopolistic) industries than for state-owned or highly monopolized firms. Second, digitalization raises productivity chiefly through three channels: it lowers managerial costs and raises managerial efficiency, it increases total factor productivity, and it optimizes the firm's talent composition. Third, these mechanisms together account for a substantial share of the overall digitalization effect. The findings underscore the role of corporate digitalization in generating qualitative productivity gains and suggest policies that facilitate firm digital adoption and complementary organizational and human-capital investments.

Keywords

New-quality productivity; digital transformation; entropy method

1. Introduction

The 14th Five-Year Plan for Digital Economy Development explicitly calls for "accelerating the construction of the digital economy and catalyzing transformations in production, lifestyles, and governance through firm-wide digitalization." On September 7, 2023, General Secretary Xi Jinping, speaking at a forum on the comprehensive revitalization of Northeast China, for the first time urged "the proactive cultivation of strategic emerging industries such as new energy and new materials, and the accelerated formation of new-quality productivity." Since its introduction, the concept of new-quality productivity has attracted widespread attention across academic and policy communities.

We define new-quality productivity as a novel form of productive capacity whose

core driving force is technological innovation and whose salient features are digitalization, intelligence, and networking.. Developing concrete indicators to evaluate the evolution of new-quality productivity and clarifying how firm digitalization affects these indicators are important steps for realizing Chinese-style modernization.

The paper makes three contributions. First, it proposes and implements a firm-level evaluation framework for new-quality productivity and uses this framework to document the relationship between corporate digital transformation and the development of new-quality productivity. Second, it identifies and empirically tests three mechanisms—management efficiency (via reduced management costs), factor reallocation (via gains in total factor productivity), and talent structure optimization—through which digitalization shapes new-quality productivity. Third, the analysis highlights systematic heterogeneity in the digitalization effect, showing that non-state firms and firms operating in more competitive industries tend to realize larger productivity gains from digital transformation.

2. Literature Review

This section briefly reviews the recent literature most relevant to this paper, organized around two strands: firm-level digital transformation and the emerging concept of new-quality productivity.

2.1. Firm-level digital transformation

A growing empirical literature examines the economic effects of firm digitalization. For example, Zhu Xian et al. (2024) use a panel of listed firms over 2011–2021 and show that digital transformation improves the composition of human capital via both technological substitution and technological complementarity effects, thereby facilitating an upgrade in talent structure. Other studies find that digitalization reduces internal production costs and external transaction costs and thereby strengthens linkages (Zhang et al., 2023). Using stochastic frontier analysis and Tobit regressions, Liu (2021) shows that managerial digitalization raises firms' input–output efficiency. Although these studies richly document channels and outcomes of digital adoption, there remains comparatively little work linking firm digitalization explicitly to the notion of new-quality productivity.

2.2. New-quality productivity

New-quality productivity—a recent theoretical development in the Chinese political-economy literature—has been discussed primarily in qualitative terms. Scholars typically characterize it as a productive capacity driven by next-generation information technologies and strategic emerging industries, whose hallmark is substantial gains in total factor productivity (Han, 2024). Some authors emphasize computational power as a central element of this new productive form (Liu et al., 2023). Others view new-quality productivity as the outcome of critical and disruptive technological

innovations built upon, and extending, traditional productive capabilities (Zhou, 2024). Several works stress that the core content of new-quality productivity lies in comprehensive improvements across the three classical dimensions of production—means of production, producers, and objects of labor (Wang, 2024).

Despite rich theoretical discussion, the literature on new-quality productivity is largely qualitative: there is a notable lack of quantitative analyses and, in particular, a shortage of operationalized, firm-level indicators to measure the development of new-quality productivity. This gap motivates the present study's attempt to construct a firm-level evaluation framework and to empirically assess how digital transformation influences new-quality productivity.

3. Research Design

3.1. Measurement of Firms' Digital Transformation

Firm digital transformation encompasses management, organizational structure, business processes and many other aspects. It is a complex, systemic process, and its measurement is a challenging problem both in academia and in practice. Drawing on the existing literature, this paper constructs a digital-transformation indicator primarily from keywords related to digital transformation disclosed in firms' annual reports. The specific procedure is as follows.

First, following the approach of Wu Fei (2021), we build a keyword dictionary for firm digital transformation covering five dimensions, including big data, artificial intelligence, blockchain, and applications of data technologies. Second, we use Python to crawl the Management Discussion & Analysis (MD&A) sections of annual reports for Chinese A-share listed firms for 2012–2022, and apply the jieba tokenizer to segment the text. We remove phrases that convey negation or negative sentiment, compute keyword frequencies for each firm's MD&A, and generate word clouds. Finally, we take the number of occurrences of the keywords in the MD&A as the firm-level measure of digital transformation.

3.2. Measurement of Firms' New-Quality Productivity Development Level

New-quality productivity, as a leap beyond traditional productivity, represents the modernization of productive forces. Its characteristics are primarily captured by the notions of "new" and "quality": the development of new-quality productivity requires new types of laborers, disruptive innovation technologies, and new kinds of production inputs.

From the perspective of tangible elements, productive forces include factors such as laborers, means of labor, and objects of labor; from the perspective of penetrative elements, science and technology are also important. New-quality productivity follows the basic connotations and features of traditional productivity. This paper attempts to construct evaluation indicators for new-quality productivity at two levels

— tangible elements and penetrative elements — to assess firms' development of new-quality productivity.

Standardization: Since all indicators selected in this paper are positively oriented, we adopt the same standardization (normalization) method:

$$= \frac{X_{ait} - minX_{ait}}{maxX_{ait} - minX_{ait}} \quad (1)$$

where a denotes the year, I denotes the firm individual, and t denotes the evaluation indicator.X_{ait} denotes the original (raw) value of the (t)-th indicator for firm I in year a. min X_{ait}、 max X_{ait}denote the minimum and maximum values, respectively, of indicator t in year a. This paper employs the entropy-weighting method to assign weights to each indicator, where there are m evaluation objects and n evaluation indicators.

Table 1. Evaluation Index System of Firms' New Quality Productive Forces

Dimension	Constituent Elements	Specific Indicators	Data Source
Physical Elements	New-Type Labor Force	Proportion of Employees with a Bachelor's Degree	CSMAR
		Proportion of Technical Staff	CSMAR
	New-Type Objects of Labor	Ratio of R&D Investment to Operating Revenue	CSMAR
		Proportion of R&D Personnel	CSMAR
	New-Type Means of Labor	Intangible Asset Ratio	CSMAR
		Fixed Asset Ratio	CSMAR
Penetrative Elements	Technological Innovation	Total Factor Productivity	CSMAR
	Green Technological Innovation	ESG Environmental Score	wind

4. Research Design

4.1. Model Construction

As an inevitable trend in the development of the digital economy, digital transformation represents one of the key strategic directions for firms' future growth. To examine the impact of digital transformation on the development level of firms' new quality productive forces, this study constructs the following model:

$$npd_{it} = \beta_0 + \beta_1 \text{digital}_{it} + \beta_2 Z_{it} + \delta_i + \theta_t + \mu_j + \varepsilon_{it} \quad (6)$$

Here, i denotes the firm and t denotes the year. The dependent variable is the level of firms' new quality productive forces npd_{it}. The core explanatory variable is the degree of digital transformation digital_{it}. Z_{it}represents a set of control variables, δ_i captures firm fixed effects, $\theta_t$captures year fixed effects, μ_j captures industry fixed effects, and ε_{it} denotes the random disturbance term.

The coefficient β_1 measures the impact of digital transformation on firms' new quality productive forces. A positive β_1 indicates that digital transformation significantly enhances the level of firms' new quality productive forces. To further mitigate potential biases arising from firm characteristics, time trends, and industry-specific factors, this study additionally controls for industry, firm, and year fixed effects.

4.2. Variable Definition and Description

Explanatory Variable. The degree of firms' digital transformation is measured using a text analysis approach to quantify the extent of digital transformation for each firm.
Explained Variable.The level of firms' new quality productive forces is calculated using the entropy weight method. For ease of interpretation, the resulting values are multiplied by 100.
Control Variables. To account for other potential factors that may influence the regression results, a series of control variables are included, such as Tobin's Q (TQ), firm ownership type (Nature), ownership concentration (OC), board size (Nd), current ratio (Lr), leverage ratio (debt), firm age (lnage), and return on equity (Profit).

4.3. Sample Selection and Data Sources

This study selects all A-share listed companies in China from 2012 to 2022 as the research sample. Firm-level data are obtained from the CSMAR database; certain indicators for the explained variable are constructed using data from the WIND database; and textual information required for the explanatory variable is collected via Python-based web scraping.
The sample data are processed as follows: ① Exclude firms marked with "ST*" or "ST"; ② Exclude firms in the financial and real estate industries; ③ Exclude samples with missing or abnormally large values for key variables; ④ Apply linear interpolation to fill in missing values for some variables; ⑤ Winsorize relevant variables at the 1% level to mitigate the influence of outliers

5. Empirical Results and Analysis

5.1. Baseline Regression Results

The baseline regression results are presented in Table 2. Column (1) reports the results without including control variables or fixed effects, where the coefficient is significantly positive at the 1% level. After adding control variables in Column (2), the estimated coefficient remains positive (0.015) and significant at the 1% level. This indicates that as firms advance their degree of digital transformation, the development level of their new quality productive forces increases significantly.

Table 2. The Impact of Firms' Digital Transformation on the Development of New Quality Productive Forces

Variable	New Quality Productive Forces	New Quality Productive Forces
	（1）	（2）
digital	0.0555***	0.0185***
	(0.001)	(0.002)
Constant	8.3104***	7.4295***
	(0.020)	(1.087)
Sample Size	24,425	23,913
Adj_R2	0.240	0.894

Control Variables	NO	YES
Firm Fixed Effects	NO	YES
Year Fixed Effects	NO	YES
Industry Fixed Effects	NO	YES

(*** p < 0.01, ** p < 0.05, * p < 0.1; robust standard errors clustered at the firm level are reported in parentheses. The same applies hereafter.)

6. Robustness Tests

6.1. Endogeneity Tests

The main conclusion of this study is that firms' digital transformation enhances the development level of new quality productive forces. However, potential endogeneity issues may still exist: (i) Omitted variables — the baseline regression may exclude some factors that influence firms' new quality productive forces; (ii) Reverse causality — firms with higher levels of new quality productive forces may be more inclined to pursue digital transformation, implying that digital transformation could be an outcome rather than a cause. Therefore, this study addresses endogeneity concerns using both the instrumental variable (IV) method and lagged explanatory variables.

6.2. Instrumental Variable Approach

To further mitigate endogeneity, this study constructs an instrumental variable for digital transformation. Following Huang Qunhui et al. (2019), the interaction term between the number of fixed-line telephones in each region in 1984 and the number of Internet users in the previous year is used as the instrumental variable.

First, digital transformation relies on Internet technologies, and the availability of telephone infrastructure and regional Internet users can partly reflect the level of local communication infrastructure and information technology development, both of which influence firms' digital transformation. In other words, regions with a larger number of Internet users and more developed basic communication facilities are more conducive to firms' digital advancement.

This study applies the two-stage least squares (2SLS) estimation method, and the results are reported in Table (3). Columns (1)–(2) present the second-stage regression results. The Kleibergen–Paap rk LM statistic is 3.219, exceeding the 10% critical value, while the Kleibergen–Paap Wald rk F statistic is 24.472, also above the critical threshold. These results indicate that the instrumental variable passes both the under-identification and weak-instrument tests, confirming its validity.

6.3. Lagged Explanatory Variables

Considering that the effect of digital transformation on new quality productive forces may exhibit a lag, the digital transformation variable is lagged by one to three periods for regression analysis. Columns (1)–(3) report the results for the first to third lags, which remain significantly positive at the 5%–10% levels. These findings suggest that because digital transformation is a long-term process, its impact on new quality pro-

ductive forces persists over time, exhibiting a lagged effect that strengthens progressively with time.

Table 3. Results of Robustness Tests

variable	New Quality Productive Forces	New Quality Productive Forces	New Quality Productive Forces
	(1)	(2)	(3)
Digital2	0.3402***		
	(0.121)		
digital		0.0171***	0.0218***
		(0.002)	(0.004)
sample	23,913	16,514	14,822
R2	0.889	0.8925	0.887
Firm Fixed Effects	YES	YES	YES
Year Fixed Effects	YES	YES	YES
Industry Fixed Effects	YES	YES	YES
Control variable	YES	YES	YES

7. Mechanism Tests and Heterogeneity Analysis

7.1. Path Analysis of Digital Transformation's Impact on Firms' New Quality Productive Forces

New quality productive forces have become a crucial engine for high-quality economic growth. As a hallmark of the modernization of productivity, new quality productive forces not only require highly skilled labor but also impose higher demands on organizational management and factor allocation. Digital technologies, with their high penetrability and strong innovativeness, exert extensive and profound effects on firms' human capital structure, organizational management, and factor allocation. This study examines the specific mechanisms through which digital transformation enhances the development level of new quality productive forces from three aspects: human capital structure, organizational management, and factor allocation.

7.1.1. Optimizing Human Capital Structure

Talent, as the primary resource, is a key driver of firm development in both traditional and modern production theories. The development of new quality productive forces places higher demands on workers' overall quality and skill levels, requiring firms to upgrade their talent structure and skill sophistication. As an important guarantee for improving efficiency and quality, the structural characteristics of human capital play a crucial role in high-quality firm development.

Digital transformation inevitably replaces some repetitive and routine jobs. At the same time, the application of digital technologies and upgrades to equipment increase the demand for high-skilled labor. Digital transformation promotes the upgrading of human capital structure primarily through the "substitution effect"

7.1.2. Technology complementarity effect

Following Jiang Ting (2022), this study employs a "two-step method" to examine the specific mechanisms through which digital transformation affects new quality productive forces. Specifically, the proportion of employees with a bachelor's degree in the total workforce (ba) is selected as a proxy for human capital structure. An increase in this proportion indicates continuous optimization of human capital structure. Empirical results show that Column (1) of Table 6 indicates a positive effect of digital transformation on new quality productive forces, while Column (2) shows that digital transformation significantly increases the proportion of employees with a bachelor's degree at the 1% level. This suggests that digital transformation increases firms' demand for highly qualified talent, ultimately optimizing human capital structure.

7.1.3. Improving Management Efficiency and Reducing Management Costs

New quality productive forces, as a new engine of economic growth, arise from emerging industries and business models. Their defining features include low input, low consumption, and high efficiency. Therefore, they place higher demands on production input and management efficiency. Moreover, the widespread application of digital technologies reshapes enterprise management, breaks down information barriers between organizations, reduces information asymmetry, lowers internal transaction costs, and improves management efficiency.

This study uses the proportion of internal management expenses (digital2) to construct an indicator of internal management costs. Management expenses directly measure the costs associated with internal management. As shown in Column (3) of Table 6, the application of digital technologies significantly reduces management expenses, indicating that digital transformation empowers management, improves efficiency, and lowers costs.

7.1.4. Optimizing Resource Allocation and Improving Total Factor Productivity

The development of new quality productive forces is driven primarily by technological innovation, which reshapes traditional production methods through technological revolutions and promotes qualitative changes in productivity. Emerging from strategic emerging industries, new quality productive forces are an inevitable result of technology-driven productivity growth. A key indicator of firm innovation is a substantial increase in total factor productivity (TFP). Digital transformation promotes deep integration of digital technologies with the real economy, enhances innovation capabilities, accelerates changes in production methods, optimizes the allocation of production factors, and comprehensively improves TFP.

This study examines firms' innovation capacity using total factor productivity (TFP), calculated via the Levinsohn-Petrin (LP) method. Column (4) shows that the coefficient of digital transformation is significantly positive at the 1% level, indicating that

digital transformation enhances firms' TFP. Under digital transformation, the application of digital technologies drives production toward automation and intelligence, promoting the modernization of productive forces.

7.2. Heterogeneity Analysis of Digital Transformation's Impact on Firms' New Quality Productive Forces

7.2.1. Ownership Heterogeneity

Firms with different ownership structures exhibit significant differences in resource endowments, business objectives, and internal governance, which may lead to different strategic decisions in response to digital transformation. These differences can affect the relationship between digital transformation and the development of new quality productive forces. Compared with state-owned enterprises (SOEs), non-state-owned enterprises face harsher market conditions and have stronger incentives to leverage digital technologies to improve productivity.

Based on the nature of the ultimate controller, firms are classified as state-owned or non-state-owned for separate regression analyses. Columns (1)–(2) of Table 7 indicate that the effect of digital transformation on enhancing new quality productive forces is more pronounced for non-state-owned enterprises.

7.2.2. Industry Competition Heterogeneity

Firms adopt different business strategies depending on the level of competition in their industry. In highly competitive industries, firms tend to pursue more flexible strategies and demand higher investment returns. Consequently, firms in more competitive industries face stronger survival pressures from market selection, which drives higher requirements for technological innovation. As digital transformation is one of the key strategic directions for firms, it complements technological innovation.

Table 7. Results of Heterogeneity Tests

Variable	Non-State-Owned Enterprise	State-Owned Enterprise	Low Monopoly	High Monopoly
	(1)	(2)	(3)	(4)
digital	0.0185***	0.0129	0.0210***	0.0028
	(0.002)	(0.011)	(0.004)	(0.002)
sample	23506	334	16102	7071
R2	0.89	0.96	0.87	0.95
Industry / Year / Firm Fixed Effects	YES	YES	YES	YES
Control Variables	YES	YES	YES	YES

8. Conclusion and Implications

Based on the fundamental connotations of new quality productive forces, this study constructs an evaluation index system for new quality productive forces and uses financial data from listed companies from 2012 to 2022 to examine the causal rela-

tionship between digital transformation and new quality productive forces. The main conclusions are as follows:

1. Digital transformation helps enhance the development level of firms' new quality productive forces.

2. Firms' digital transformation primarily fosters new quality productive forces by optimizing human capital structure, reducing management costs, and improving the efficiency of production factor allocation.

Based on the above findings, several implications can be drawn:

1. Promote innovation in next-generation digital technologies. such as big data, artificial intelligence, and blockchain to provide technological support for firms' new quality productive forces. On one hand, firms should focus on R&D investment in next-generation information technologies to seize the technological high ground and support the deep integration of the digital and real economies. On the other hand, enhancing the digital industrialization level, expanding application scenarios for digital technologies, and enabling the digital economy to empower the real economy are essential.

2. Cultivate innovative talent and build a high-quality workforce.As the most dynamic element of new quality productive forces, the new-type labor force is crucial for their formation. Therefore, it is necessary to further improve talent training systems, establish sound talent incentive mechanisms, and build high-level talent teams to provide human capital support for the development of new quality productive forces.

Acknowledgements

This research was supported by the Sichuan Provincial College Students' Innovation and Entrepreneurship Training Program (Project No.: S202410615215; S202410615214). We gratefully acknowledge this support.

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